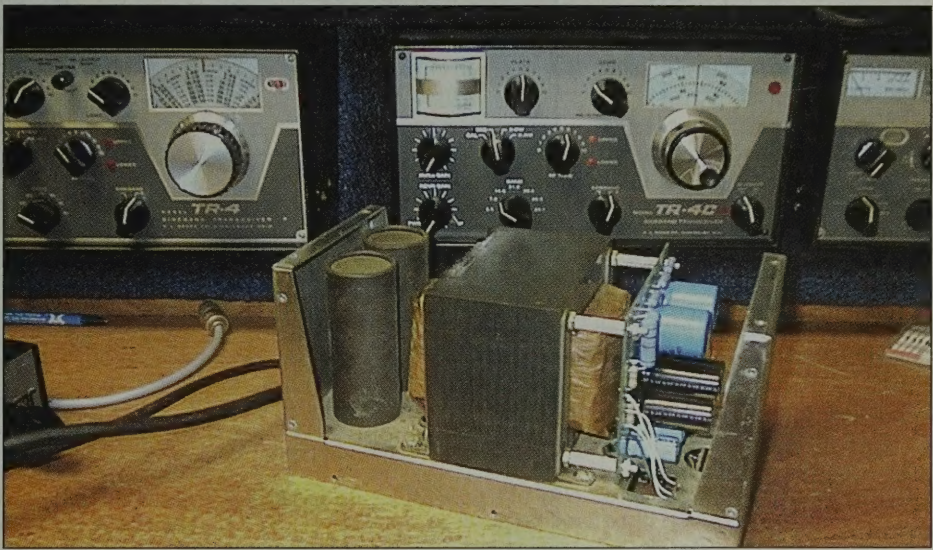
Updating the Drake AC-4 High Voltage Power Supply

Drake radios are hard to kill. But those AC-4 power supplies are showing their age.

Mike Bryce, WB8VGE



Updated AC-4 power supply. The old capacitors are no longer connected.

Collecting and using vintage radios has become quite popular. In fact, a quick glance at the prices being paid for old tube based radios on Internet auction sites can be quite an eye opener. Bet you wish you still had your old Hallicrafters HT-32 SSB transmitter, don't you?

When I designed an upgrade for the popular Heathkit HP-23 power supply, I got a lot of requests to retrofit other old high voltage supplies.[1] The most frequently requested update was for the R. L. Drake AC-4. This was used with all Drake vacuum tube transceivers in the TR series, as well as with the T4X series of transmitters. As with the Heathkit HW-101 transceiver, the Drake transceivers are over 30 years old. Good heavens, the Drake TR-3 is over 40.

Old Supplies, Old Problems, New Fixes

As with the Heathkit HP series of high voltage power supplies, the Drake AC-4 are failing because the high voltage electrolytic filter capacitors are drying out and shorting out. If you're lucky instead of fireworks, the sound you will hear is hum on receive and buzz on transmit because the capacitors' equivalent series resistance (ESR) has become so high that they don't filter anymore.

If it were 1968, the fix would be as simple as calling up Drake and ordering new capacitors. Those days are long gone. Drake sold off all of their parts several years ago.

Finding new high voltage electrolytic capacitors that fit these old supplies is next to impossible. Granted, you can sometimes get *new old stock* (NOS) parts. But, while unused, the NOS parts are just as old as the ones you're replacing. If they do work, they may not work as well as they would have 30 year ago.

To complicate things even more, some of these transceivers and power supply combos may have been sitting in a closet for decades. When they are sold on auction sites, the first thing the guy does after the UPS truck backs down the driveway is to *plug 'er in.* Since it's been years since the high voltage electrolytic capacitors have had power applied to them, they look like a short circuit to the rectifier diodes. This almost always takes out one or more diodes in the supply as soon as the switch is flipped to the ON position. So now the problem becomes twofold: the capacitors need to be replaced along with the rectifier diodes.

A Slow Start-up

One way to prevent this kind of damage is to use a variable voltage Variac transformer on the ac line into the power supply. In a nutshell, this device is an adjustable transformer. You literally dial up the voltage you want by twisting a knob. You set the Variac to a lower line voltage than what the power supply would normally operate from. The exact value is up to you and your experience, but I like to start things off with about 30 to 50 V. After a few hours you increase the voltage slightly. After a day or so you will be able to dial up full voltage to the supply.

This is time consuming and does not always guarantee the power supply will work as new. On the other hand, most of us do not have access to a Variac transformer. I know of some hams who lack such a device and use a 100 W light bulb placed in series with the primary wiring. This light bulb limits the current and thus reduces the voltage to the supply.

The Fix

The fix is the same as that applied to the old Heathkit supplies. Use new modern, high voltage, high temperature electrolytic capacitors along with new diodes having

[1]Notes appear on p 61.

SHORT TAKES

Nec2Go by Nova Plus Software

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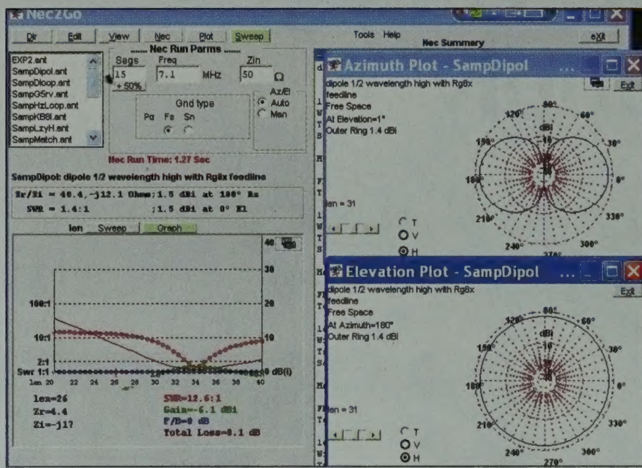
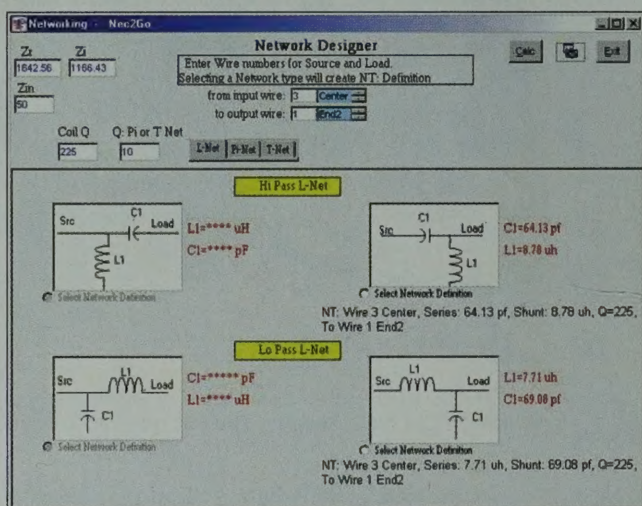
You never know when, or how, you'll discover a new tool. Recently I saw a reference to a program called *Nec2Go*, an antenna modeling application for *Windows* written by Patrick Wintheiser, WØOPW, in an e-mail I received from a friend. As I read the description of the program, I began to realize that Pat's approach to antenna design software was a vast improvement over other available programs.



Nec2Go uses variables in equations to develop straight lines that are defined in a three dimensional space of X, Y and Z. These are needed in the "Wires" definitions used by the *Nec2Go's NEC2* design engine.

For simple horizontal or vertical dipoles, variables can be defined for the X, Y and Z coordinates. If you are designing antennas with several horizontal or vertical parallel elements, such as Yagis and square loops, you assign variables for the X, Y and Z axis.

Five arithmetic operators and five functions are included. They are +, -, *, /, X^Y, SQR, Sin, Cos, Shift and Rotate. These are used with more complicated geometric shaped antennas such as slopers, discone, quads, rhombics, phased arrays and Corner reflector. Yes, you might have to dig out those old text books from high school or college. The *ARRL Antenna Book* will also prove useful.



Nec2Go's Network Designer feature.

A Software Toolbox

If you can define an antenna system by using the above operators and functions, then *Nec2Go* is for you. Sixteen sample programs are included. By playing with these samples you will get a good idea of the capabilities of this software. You can also import any of the many available designs.

In the program, you assign values to any variables. These variables may be from the geometry of the antenna elements, inductance and capacitance from a loading coil, conductance of the antenna elements etc. You can view a sketch of your design. A list of the variables can be viewed as well as their values, and can be easily modified in the design antenna file. *Nec2Go* provides views of elevation, azimuth and 3-D radiation pattern. The sweep function allows the frequency and each variable to be swept through various values.

Analyses of the antenna design will give values for impedance, SWR, front to back ratios and antenna gain. This information is displayed in graphical and numerical form. By using the sweep function, a design can be optimized for element length, distance between elements, material of the elements, etc.

Nec2Go includes a *coil designer* module. There are four fields of data: frequency, inductance, capacitance, resistance. After you specify the parameters, *Nec2Go* shows you the length and size of wire, turns per inch and total number of turns. From this information, a trap can be designed and built. The inductance and capacitance can be inserted into the antenna program as a load. A *coil optimizer* tool finds the optimum, number of turns for a given inductance, coil length and diameter.

Network Designer

Of course, every antenna needs a transmission line. This might be ladder line, twisted pair or a coaxial cable. The *NEC* engine does not have the capability to design the coupling network between the antenna and transmission line-transceiver system, so Pat has developed a very powerful tool to do this design for you automatically with *Nec2Go*. It is called *Network Designer*.

The Network Designer takes the impedance information from the analyses of the antenna design and allows you to choose a method of matching the antenna to the transmission line.

You can choose between L, Pi or T networks. After you make the choice, the Network Designer calculates the best combination of capacitance, and inductance to use. It then automatically inserts these values into your program in the appropriate place. This same tool can also be used to design phasing networks.

Impedance matching can also be accomplished by using two transmission lines in series that have differing characteristic impedances. The Network Designer allows you to select a coaxial cable from a long list. These cable types and their lengths are then automatically inserted into the design program.

Information on ground conditions such as conductivity, permittivity and relative quality are presented so that the designer will have a better idea of the actual radiation patterns. There is a table of metal conductivities for various materials used in the construction of antennas.

Nec2Go is available from Nova Plus Software at **www.nec2go.com**. The best approach is to download the demo version first to see if it meets your needs. Read the Help file as well as the README file, which contains a list of the features of this program. If you like it, you can purchase the full version for a modest cost of $39.95. QST

greater voltage and current ratings. Then put the whole shebang on a printed circuit board (PCB) that will fit in the Drake AC-4 high voltage power supplies. I call these the *R* series upgrades. The "R" stands for replacements. A complete kit of parts or just the PCB along with detailed instructions is available for those who don't like hunting for parts.[2]

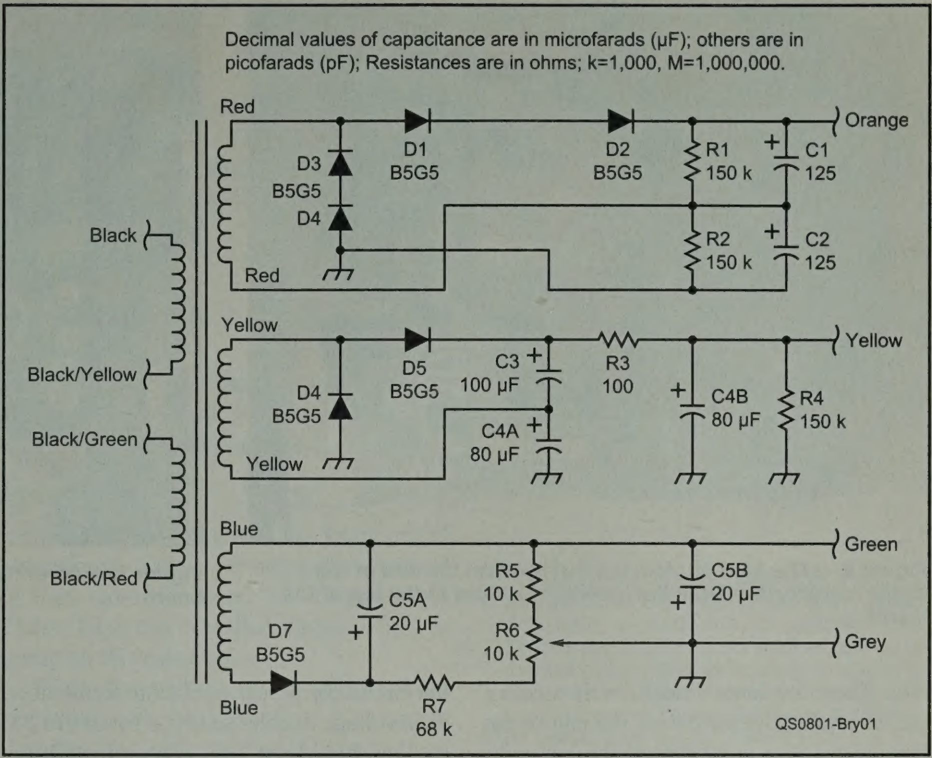


Figure 1 — Schematic diagram of modified portion of Drake AC-4 power supply. Replaced parts with new values are listed below. Digi-Key parts are available from www.digikey.com, Mouser parts from www.mouser.com.

C1, C2 — 150 µF, 450 V electrolytic capacitor (Digi-Key p7430-nd).
C3-C5 — 100 µF, 350 V electrolytic capacitor (Digi-Key 493-1222-nd).
C5A, C5B — 47 µF, 350 V electrolytic capacitor (Digi-Key 493-1221-nd).
D1-D7 — 1N5399 rectifier diode (Mouser 583-1N5399-B).
R1, R2, R4 — 150 kΩ, 3 W resistor (Mouser 283-150K).
R3 — 100 Ω, 10 W resistor — two 200 Ω, 5 W in parallel (Digi-Key 200w-5-nd, Mouser 286-200).
R5 — 6.8 kΩ, 1 W resistor (Mouser 293-6.8K).
R6 — 10 kΩ, 1 W resistor (Mouser 293-10K).
8-32 × 1 inch long spacer (Mouser 534-8431).
4 lug terminal strip (Mouser 158-1004).

Don't Fix What Ain't Broke

If you have a healthy AC-4 and it's working fine, then don't fix it! Perhaps the best avenue here would be to get a PCB, and place the PCB in the supply's manual. Then when the supply fails, you have the PCB. Stuff the PCB with factory new capacitors and you're up and running.

Changes That Were Made

The high voltage electrolytic capacitors were increased in value from 120 µF to 150 µF. The voltage ratings on the capacitors for both plate supplies have been increased to 450V.

The bleeder resistors were changed from 2 W to 3 W flameproof versions. No changes in resistance values were made.

The Details

The upgrade replaces all the old high voltage capacitors with new state-of-the art devices. The high voltage capacitors used in the plate (650 V) supply have been changed to 150 µF at 450 V. In the Drake AC-4, both the plate and low voltage supplies use a voltage doubler circuit to generate the necessary voltages required by the transceivers.

The Drake AC-4 schematic is almost a carbon copy of the Heathkit HP-23 high voltage power supply. In fact, I know of several hams who have shoehorned one of the original HP-23R PCBs into the Drake AC-4 chassis. It's a daunting task that involves moving the transformer, trimming the PCB and drilling lots of holes. It's not a project for the faint of heart.

There is a difference in how the low voltage supply is designed on the AC-4.[3] In the Heathkit HP-23 series, Heath's engineers decided to use a filter choke in the 300 V supply. The bean counters at Drake decided to go with a resistor capacitor input instead of the choke. Both circuits work equally well, and resistors are cheaper than filter chokes (lighter in weight, too), so Drake chose the resistor input. In the Drake AC-4 supply, some of the first units off of the assembly line used a 5 W, 100 Ω resistor. After time, this resistor would open and fail and they changed to 10 W in later units. Instead of one large 10 W resistor, I use two 200 Ω, 5 W resistors in parallel. The result is a single 100 Ω, 10 W resistance.

The bias supply in the AC-4 is a real sore spot for most Drake owners. If the bias supply starts acting up in an older AC-4 supply, it can cause all kinds of problems. These range from buzzes and hums in the receiver's audio to the transmitter output tubes melting. Needless to say, the bias supply upgrade was high on the list of fixes. The upgrade increases the value of the bias capacitors from 22 to 47 µF and from 300 V to 350 V. The diodes used in the plate, low voltage and bias supplies are now 1N5399s with a 1.5 A at 1000 V rating.

Inside the AC-4 power supply

Taking off the cover of an AC-4 and you will quickly see it's a tightly packaged supply. There's not much room inside. But lucky for us, capacitor technology has vastly improved in the past 30 years. You can easily swap out one of the older capacitors and have enough room to install three of today's capacitors. And that's exactly what I did.

Enter the AC-4R

The AC-4R is the replacement for the majority of the pieces and parts inside the old AC-4 power supply. The low voltage (screen) capacitors and bias capacitors are removed and trashed. The original high voltage diodes, the low voltage diodes and the bias diodes are cut out and removed. The resistor used in the input circuit for the low voltage section is also removed.

The only original capacitors left on the chassis are the two high voltage electrolytic capacitors. They are left just to maintain the original appearance. They are not used in the upgrade and could be removed from the chassis if you wish. About the only thing left inside are the power transformer and bias set trimmer mounted on the side.

Now, all the parts that were cut out and removed are replaced with new ones installed on a double sided PCB. This PCB mounts on standoffs on the transformer bell end. The PCB is held in place by the original hardware used to hold the transformer together.

When the transformers were assembled, the manufacturer used long 8-32 screws and

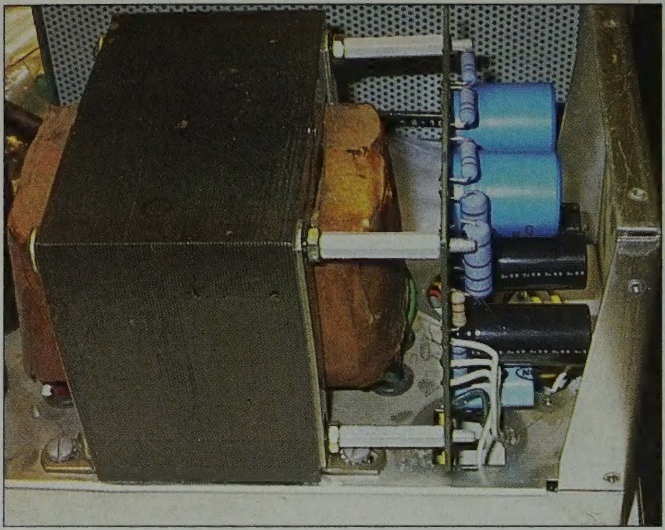


Figure 2 — The PCB stuffed and installed on the end of the power transformer. Note the bleeder resistors at the top of the board.

Figure 3 — All of the original AC-4 circuits now fit on this single board.

nuts. There are some threads on the ends of the hardware sticking out on the end of the transformer that point toward the low voltage and bias capacitors. An 8-32 aluminum standoff that is 1 inch long is screwed onto these threads.[4] The PCB is then mounted on the side of the transformer via the standoffs.[5]

Since the bleeder resistors have also been moved to the PCB, they are mounted so they are at the very top of the PCB. This way, the heat they produce is not allowed to heat up other parts mounted on the PCB. Likewise R3, now comprised of two 200 Ω, 5 W resistors in parallel, are mounted on the top half of the PCB to allow for cooling.

The high voltage capacitor along with the low voltage and bias capacitors are also mounted on the PCB. All high voltage, low voltage and bias diodes are also mounted to the PCB. The only component not installed on the PCB is the bias set trimmer. This trimmer needs to be set so the bias voltage is correct for a particular radio. Placing this control on the PCB would require cover removal to set the bias.

Installation and Checkout of the PCB

The PCB makes assembly of the AC-4R quick and easy; there's no rule that says you can't duplicate the circuit on a hunk of perforated project board. If you go this route, place the bleeder resistors at the top of the perf board to help move the heat away from the capacitors. Use heavy gauge wire between the diodes and capacitors.

Perf board is somewhat soft, so use backing washers between the standoff and the perf board. If you perf board the circuit, I would assemble each section one at a time. Then, using a low voltage transformer, test the circuit for proper operation. Remember, it's a voltage doubler so if you squirt in 12 V ac, you should see 24 V dc coming out the other end. If you do, then that section of the circuit is working and you can now build the next section.

If you use the PCB, it should be stuffed before mounting it into the AC-4 chassis. It is best to start by installing the diodes first. Make sure you match the outline on the silk screen to the diodes you are installing.

Next, mount the three bleeder resistor so they are about ¼ inch above the PCB. This way, air movement will help cool them and prevent damage to the PCB from the hot bleeders.

Next, mount the two 200 Ω resistors. They too need to be mounted above the PCB by about ¼ inch. The easiest way to do this is to take two of the standoffs and slip one under each end of the innermost resistor. Solder the part in from the top side of the PCB. The idea is to keep the resistor parallel to the PCB all the while preserving the ¼ inch air gap. Do the same for the outermost resistor.

Be aware that the electrolytic capacitors can only be installed one way. There is a silk screen on both sides of the PCB, so that should help when it comes to mounting these. You will also note that all of the negative leads of the capacitors point toward the bottom of the PCB. If you see one out of place, you must remove the capacitor and then reinsert it correctly. Check all the capacitors before soldering them into the PCB.

After you have the PCB stuffed, double-check for the correct placement of the diodes and electrolytic capacitors. When you're happy with your work, solder the wires to the bottom pads of the PCB, then mount the PCB to the standoffs that you have mounted on the transformer's end cap.

Wiring Up the AC-4R

This is the hardest part. You have to wire the PCB to the various sections of the transformer. I suggest you use colored wire to avoid confusion. The PCB is silk-screened with a color for each pad. I suggest you follow this color code. It was designed to help troubleshoot the supply should that need arise.

Basically, you have to connect the high voltage secondary to the PCB. Then the low voltage and the bias supply secondary voltages. Once the inputs have been wired, all you have to do is connect the output of the PCB to the multi-wired cable going out to the radio. It's not hard to do but it can be confusing. I was going to include a color code for the original Drake AC-4 supplies but have learned that Drake did not follow the same color code throughout the AC-4's production life.

Testing the New AC-4R

First read and carefully consider the *Switch to Safety* sidebar. Do not connect the supply to the drake radio equipment at this time. Without a radio connected, you need to short out two wires in the primary circuit to allow the supply to power up without connecting it to a Drake radio. When you short out the power switch wiring, there is no way to tell if the supply has 120 V ac applied to it and that the supply is producing high voltage!

On the large multi pin connector (this is the cable that goes from the power supply to the transceiver) short pins 1 and 2 together. You can use a short piece of insulated hookup wire to short the two pins together. Place some tape across the small jumper to

Switch to Safety

First and foremost, safety first! The voltages lurking inside the AC-4 are deadly! A misplaced fingertip may well place your name in the *QST* Silent Key section. So, if you don't have the talent, don't have the experience or don't have the test equipment necessary to perform these tests, then don't! Have someone else verify the operation of the supply if you can.

keep it in place.

Instead, you can also connect the blue and brown wires together inside the chassis of the AC-4. These wires run to the multi pin connector. These two wires are on the primary side of the transformer and not the blue wires used in the bias circuit.

High Voltage +650 V Test

Before you begin testing, make sure your volt-ohm-milliameter (VOM) can safely measure 1000 V dc and the test leads are in good condition. Preset your VOM to read 1000 V dc. Attach the negative lead to the chassis and the positive lead to the orange wire located on the single lug terminal strip. The white/orange wire connects to this point, too. This is the wire going from the PCB to the multi-wired cable. If it is easier for you, then you can measure all the different voltages from the pads on the PCB. You can get to all the pads from the front of the PCB.

With the jumper across pins 1 and 2, as soon as you plug in the supply, it will power up! Plug in the supply. If you hear cracking sounds, snapping noises, see or smell smoke, remove the power cord from the supply at once. If the supply is operating normally, you should read the following:

- The orange wire should read at least 650 to 750 V dc.
- The yellow wire should be at least 290 V dc.
- The green wire should read a negative voltage that will vary as you adjust the bias trimmer.

They may vary as much as 20% and be within limits.

Remove the power cord from the 120 V source and remove the jumper from pins 1 and 2. Discharge the capacitors with a resistive shorting stick. If you have the correct voltages, then tidy up the wires and reinstall the cover. The cover must be installed over the AC-4. There are high voltages present on the PCB. The cover keeps cats, kids and critters from harm's way. The new AC-4R can now be put to use.

Plug in your transceiver and power up the radio. Check once again for smoke, fire and flames. Now, set the bias trimmer on the side of the supply according to the manual of the transceiver or transmitter you have running. Once the bias is set, you're ready for HF operation, as long as the radio also works.

Wrap-up

With the new upgrade, the Drake AC-4 should now outlast yet another generation of ham radio operators. Yes, today even a Drake TR-4 can be called vintage. They're going on 30 years old!

There's something quite magical about operating with vintage radios. It's hard to describe, but once you walk into a shack with real radios playing, you'll never forget the sights and smells. It's part of our radio heritage. So, fix up those old power supplies and keep those old Drake TR-3, TR-4 and T4X radios on the air. Let's keep our history alive on the bands.

Notes

[1]M. Bryce, WB8VGE, "Upgrading the Heathkit HP23 Power Supply," *QST,* Oct 2003, pp 58-61.

[2]A complete kit of parts including the PCB and detailed assembly and installation instructions may be purchased for either supply from SunLight Energy Systems, 955 Manchester Ave SW, North Lawrence, OH 44666. The kit price is $65 plus $5 shipping. Additional information is available via e-mail at **prosolar@sssnet.com**.

[3]The term "low voltage" can be a bit confusing when we talk about high voltage power supplies. The low voltage used in these supplies normally set between 250 and 400 V dc. It's not the 13.8 V dc we see in today's gear.

[4]In some Drake AC-4 supplies, the transformer has the bolts and nuts installed on the opposite end. You can remove the long screws, turn them around and reassemble them. Some transformers do not have enough extra threads sticking through to allow the standoffs to be attached. Simply remove the nuts on the transformer and then screw on the standoffs.

[5]The Drake AC-3 supply is electrically identical to the AC-4. They do not share the same footprint, however. Installing the AC4R PCB on the AC-3 chassis is not hard. I've done one. You will have to drill some holes to mount the PCB.

[6]M. Bryce, WB8VGE, *Emergency Power for Radio Communications.* Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9531. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

Photos by the author.

Mike Bryce, WB8VGE, has written many QST *articles and is the author of the ARRL book* Emergency Power for Radio Communications. *You can reach him at 955 Manchester Ave SW, N Lawrence, OH 44666 or at* **prosolar@sssnet.com**. *He also maintains a Web site at* **www.theheathkitshop.com**. QST

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NØAX

HANDS-ON RADIO

Experiment #60 — Smith Chart Fun #2

Last month's column introduced the Smith Chart and showed how it was constructed. This month, we're going to add more information to the chart in a way that helps design impedance transformation circuits.

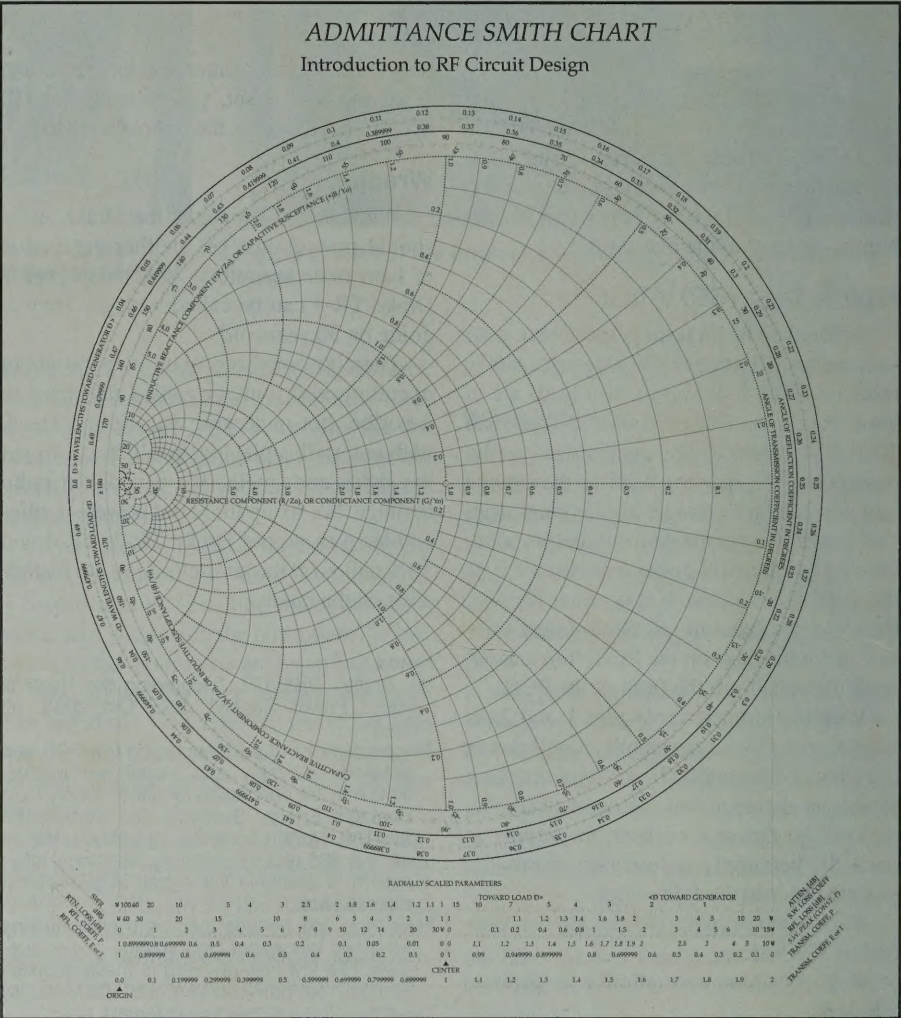

Figure 1 — The admittance-only Smith Chart is inverted from the impedance-only Smith Chart both horizontally and vertically about the center point.

Free Admittance!

You now understand how the Smith Chart is created by mapping the usual impedance coordinates from an open-ended rectangular grid into a finite circle. Impedance, however, is not the only way to specify the ratio of voltage and current. Admittance (Y) is the reciprocal of impedance. This reciprocal, $Y = 1/Z$, is just the ratio of current to voltage.

Impedance is sufficient for most problems, but admittance comes in very handy at times. For example, to calculate the combined impedance of three impedances in parallel, $Z_{EQ} = 1 / [1/Z_1 + 1/Z_2 + 1/Z_3]$. If those impedances were first converted to admittances, $Z_{EQ} = 1 / [Y_1 + Y_2 + Y_3]$. Stated another way, $Y_{EQ} = Y_1 + Y_2 + Y_3$. Admittances in parallel add together, just as impedances in series add together.

What's it All About?

Impedance is made up of resistance (R) and reactance (X). Similarly, admittance is made up of conductance (G) and susceptance (B). G and B are the reciprocals of their counterparts in the impedance world; $G = 1/R$ and $jB = -j/X$. Note that $1/j = -j$. Just as the rectangular grid of impedance points can be mapped into the circular Smith Chart, so can the rectangular grid of admittance points. Figure 1 shows the result.

Let's Go to the Charts!

To obtain Figure 1 from a "regular" impedance Smith Chart, first flip the chart horizontally about a vertical line drawn through the center of the chart. That changes all of the constant resistance circles, touching at the right-hand side of the resistance axis (at which $R = \infty$ and $G = 0$), into *constant-conductance circles* that touch at the left-hand side of the axis (where $G = \infty$ and $R = 0$). All of the *constant susceptance* arcs still start on the circle's outer rim, but now meet at the left-hand side of the horizontal axis at $G = \infty$, just as the constant-reactance arcs met at $R = \infty$.

Now, flip the chart vertically about a horizontal line drawn through the center of the chart. This accomplishes the final part of the transformation, adding the effect of the minus sign in the equation $jB = -j/X$. Download an admittance-only Smith Chart from **ece.wpi.edu/~ludwig/EE514/Y_ee3113.pdf** and look carefully at the labels on the outer circle axis near the left-hand side of the chart. You will see that the top label, for example, is INDUCTIVE REACTIVE COMPONENT ($+jX/Z_0$), or CAPACITIVE SUSCEPTANCE ($+jB/Y_0$). Susceptance is normalized, just like reactance, by dividing it by the characteristic admittance ($Y_0 = 1/Z_0$) of the transmission line. If $Z_0 = 50\ \Omega$, then $Y_0 = 0.02$ S. Note that the symbol for conductance, formerly an inverted omega, is now the letter S for siemens, the unit of admittance.

The Z and Y Smith Chart

Many problems in transmission lines are best worked out using a combination of Z and Y. Some parts of the problem are easiest working with Z, while others are easiest using Y. It would be awfully inconvenient to

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AC-4 POWER SUPPLY

The R. L. Drake Model AC-4 is a complete power supply capable of supplying all of the required voltages for our TR-3 and TR-4 transceivers as well as our T-4 and T-4X transmitters with the proper filtering and regulation. The unit may be operated from 120 or 240 VAC, 50 or 60 cycles.

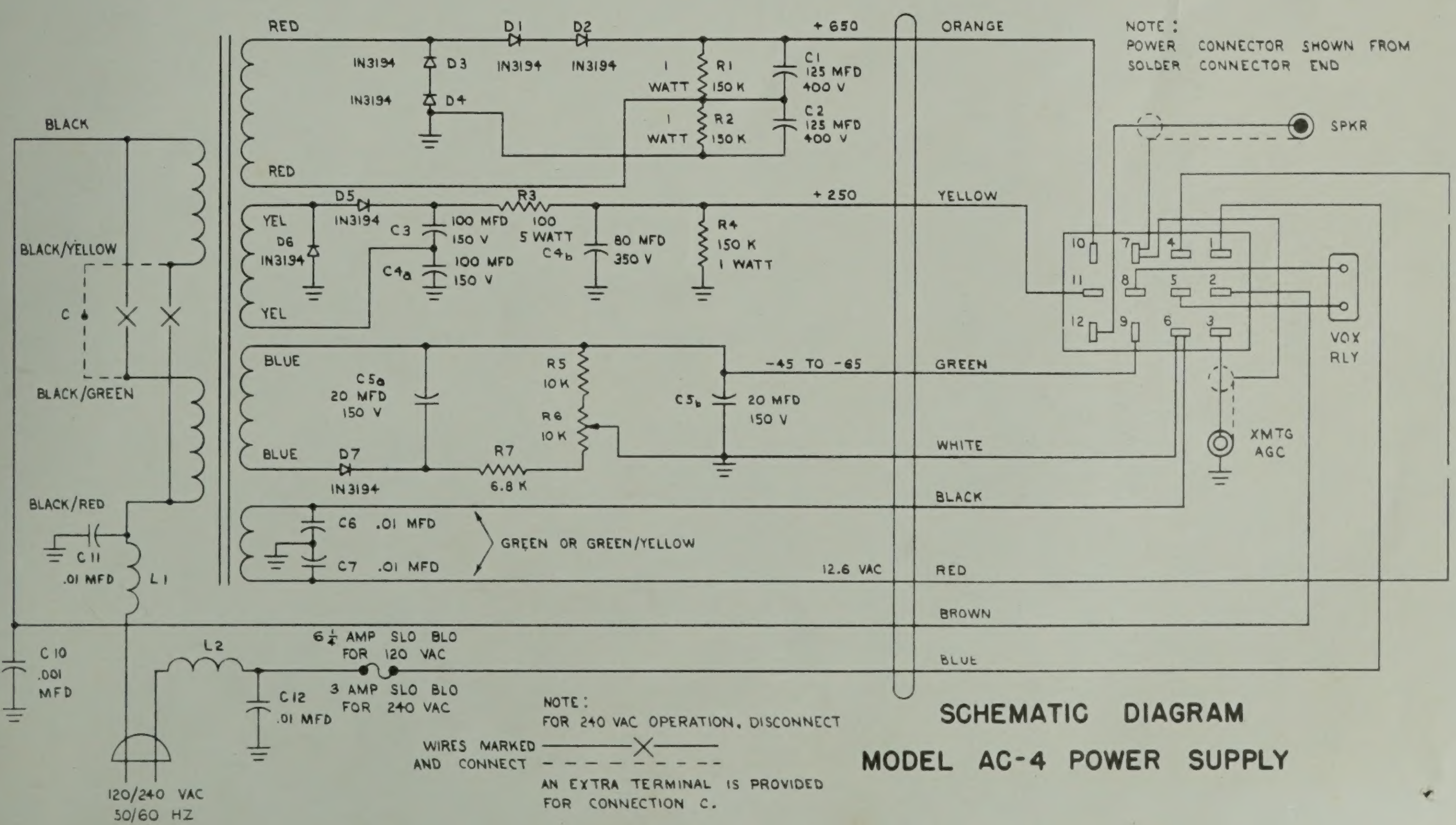
It is designed to fit into our MS-4 Matching Speaker or RV-4 Remote VFO to become a single unit.

To mount it in these units, slide it in from the rear so that the line cord and power cable face outward. Fasten it in place with the four studded rubber feet provided with the unit.

To connect, plug the female power connector on the end of the power cable into the male connector on the rear of the TR-3, TR-4, T-4 or T-4X. (See installation instructions for the appropriate equipment.) A 6" lead terminated in a female phono plug extends from the power connector for connecting the MS-4 Speaker when the unit is used with our TR-3 or TR-4 transceivers.

The bias adjustment should be set properly before any operation is attempted. (See Tune Up procedure.)

IMPORTANT: Never ship the AC-4 mounted inside the Speaker or Remote VFO case or serious damage to the case will result.



SCHEMATIC DIAGRAM
MODEL AC-4 POWER SUPPLY